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New Techniques and Developments in Meteorological Balloons

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M. Sharenow

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36. New Techniques and Developments in Meterological Balloons

M. Sharenow
Atmospheric Sciences Laboratory
USAECOM, Fort Monmouth, New Jersey

36.1 INTRODUCTION

During the past few years, studies and investigations have been pursued to meet both the existing requirements of the Army and to explore new techniques and developments in order to improve the performance of meteorological balloons. The most recent studies, devoted to the coating of neoprene balloons with various materials, have two basic goals: (1) increasing the bursting altitudes under arctic nighttime conditions, and (2) increasing ascent rates in general.

36.2 DISCUSSION

36.2.1 Metallizing

Under the first category, attempts were made to change the radiative and absorptive properties of a balloon by applying a thin, metallic coating in the expectation of keeping the balloon at a warmer than ambient temperature. Materials investigated were aluminum, magnesium, and nickel, with the greater stress on aluminum. This paper will discuss aluminizing only.

Aluminum powder is dispersed by either spraying or brushing on a neoprene adhesive. The solvents used in the preparation of the adhesive cause the vulcanized neoprene to swell and to reduce its tensile strength. However, this effect disappears upon evaporation of the solvent, unless the film has been under stress while in contact with the solvent. For example, if application was made to an expanded film, permanent distortion or rupture could occur.

36.2.2 Infrared Tests

Infrared absorption tests were carried out on small, standard, black, and aluminized films prior to any flight tests. It was found that the temperatures inside the black balloon and an expanded aluminized balloon were warmer than the temperature inside a standard balloon, presumably as the result of a greenhouse effect in the aluminized balloon (Morel et al, 1968).

Daytime and nighttime flight tests were made at Belmar, N. J., with temperature elements inside both aluminized balloons and control balloons, and the daytime comparisons exhibited quite large differences, the temperatures inside the aluminized balloons being greater in varying amounts depending on altitude by as much as 30°C and as little as 2°C. At night, the differences were small - the temperatures inside the aluminized balloons were a couple of degrees warmer up to about 30,000 feet, then they were either the same or a couple of degrees cooler than the control balloons at greater altitudes. This pattern was reversed on one pair where the nighttime balloon was aluminized only on the top half. There were five sets of flights where temperatures were measured inside.

36.2.3 Arctic Tests

A number of balloons were flown during the arctic winter night at Thule, Greenland. The first set was flown in February 1969 and another set in December 1969, and January 1970. The balloons fabricated in February 1969 were early models and were thicker-walled, shorter balloons weighing 1200 grams and approximately 80 inches long. The models for the December 1969 - January 1970 flights were 1400-1600 grams and were 110 inches long. These balloons were not intended to be 100,000-foot balloons when uninflated. Control balloons were flown with each of the aluminized balloons in February 1969.

Fifteen pairs of balloons were flown in February 1969. It was determined from the usable data (Table 36.1) that aluminized balloons performed better in altitude by 2 to 1, and in rate of rise by 4 to 1, the altitude differences varying from 4000 to 30,000 feet, and the rate of rise differences from zero to as much as 250 ft/min faster. Since all the balloons were not flown under identical conditions of complete darkness, the results can be considered only as being qualitatively correct.

Table 36. 1. Aluminized Balloons, February 1969

BURST ALTITUDE (feet)				RATE OF RISE (ft/min)	
ALUMINIZED (feet)	TIME	CONTROL (feet)	TIME	ALUMINIZED	CONTROL
64,429	Twi	53,366	N	1,273	1,093
53,312	Edge D	74,787	D	1,215	1,056
57,254	Twi	61,027	Edge N	1,090	1,218
80,000	D	56,539	N	1,320	1,079
76,752	D	56,319	Twi	1,220	1,246
51,768	Twi N	58,222	N	1,187	1,124
91,997	* Edge Twi	55,351	Twi	1,383	1,112
84,709	* Twi	54,921	Twi	1,248	1,343
81,516	Twi	71,591	Edge N	1,208	1,067
84,672	Edge Twi	63,802	Twi	1,321	1,011
48,674	N	52,795	N	1,232	1,242
72,047	Edge Twi	55,072	Twi	1,362	1,252

* 1/2 Aluminized (top)
Twi = Twilight
N = Night
D = Day

The second set of balloons flown in December 1969, and January 1970, all performed under complete darkness. Unfortunately, no control balloons were flown with the second set. Five of the balloons flown in December 1969 were aluminized, ML-537 type (100,000 ft). These did not perform well (Table 36. 2). Minimum temperatures were as low as -73°C. Nine other aluminized, all-zone type, ML-607 non-standard balloons were flown in January 1970. These performed better. However, the minimum temperatures had warmed up substantially by early January, 1970; therefore, no conclusions could be drawn.

The ascent rates of the all-zone aluminized balloons are considered good in spite of the fact that they were underinflated by about 300 gms. Immediately following the flights of the all-zone, aluminized balloons (1-5 January 1970), a series of all-zone, non-aluminized balloons (Table 36. 3) were flown (6-13 January 1970).

Table 36.2. Aluminized Balloons, December 1969

BALLOON TYPE	ALTITUDE(ft)	RATE OF RISE (ft/min)	NOZZLE LIFT
ML-537	63,133	951	2600 grams
	59,964	919	"
	59,285	886	"
	67,664	935	"
	60,922	919	"
January 1-5 1970			
All Zone Type (ML-607)	79,754	1,066	"
	99,259	998	"
	94,472	1,098	"
	100,600	940	"
	102,110	935	"
	97,736	1,122	"
	104,170	994	"
	98,892	1,030	"
	71,969	1,010	"

Table 36.3. All Zone Non-Aluminized Balloons, 6-13 January 1970

ALTITUDE (feet)	RATE OF RISE (ft/min)
80,881	867
91,106	843
81,300	886
82,152	1,017
84,238	928
113,045	1,063
86,073	894
115,050	963
111,762	967
93,645	967
86,047	1,003

The minimum temperatures encountered on these flights were very similar to those encountered on the flights of the aluminized ones. The aluminized balloons were superior to the untreated balloons in both bursting altitude and ascent rate. Seven of the balloons exceeded 90,000 feet, compared to five of the twelve untreated balloons. Also, seven of the nine aluminized balloons were near or greater than 1000 feet per minute compared to three out of twelve for the untreated balloons, this in spite of the fact that the untreated balloons had more free lift on most flights.

36.2.4 Thermoplastic Coating

In attempts to incorporate several desirable properties into a balloon film, materials can either be incorporated into a compound or laminated to an existing film. Kraton, a thermoplastic elastomer produced by Shell Oil Corp., has shown promise both when blended with neoprene compounds and when laminated with them. Attempts to produce balloons from Kraton alone by solution-dipping have not proven successful.

Some results of the lamination technique with Kraton being sprayed or brushed on are now available. The most pronounced effect of coating with Kraton is to increase the differential pressure of a balloon. The first tests were made on 100-gm balloons in which the differential pressure was nearly doubled initially and remained well above that for an untreated balloon during inflation to burst. The differential-pressure increase was not so marked on larger balloons.

There is good indication that improvement in ascent rate is occurring in the larger balloons as a result of the Kraton coating. A balloon with higher internal pressure tends to deform less during ascent and has a better aerodynamic shape as a result. The smaller balloons are less affected by this effect; for example, normally inflated, 100-gm balloons have a fairly high differential pressure. As the balloon size increases for a given compound, the effect should be more beneficial.

Results of flights with Kraton-coated, 300-gm balloons are given in Table 36.4. These balloons were coated on the inside, resulting in an increase in balloon weight of about 25-30 percent. Initial balloon weights were 240-270 gms and increased to 320-355 gms. Ascent rates of the coated balloons exceeded those of the control balloons in five of the six flights by from 20 to 166 feet per minute. The coated balloons did not reach as high altitudes, however. Kraton is attacked by ozone - thus in some instances it might be more desirable to use it on the inside of a balloon.

Balloons were also fabricated in the 1400 gm (Table 36.5) weight range, of which 200-300 gms represented the Kraton. These balloons were essentially the

Table 36.4. Kraton-coated Balloons, 300 gm Balloon (1400 gm free lift (F. L.) except one at 900 gm F. L.)

BURSTING ALTITUDE (feet)			RATE OF RISE (to common alt)	
Time	Kraton	Control	Kraton	Control
Night	46,400	56,400	1,255	1,094
Night	50,400	51,000	1,072	1,052
Night	43,400	46,000	1,142	1,090
Night	47,300	49,200	1,000	1,168
Day	58,700	61,300	1,210	1,044
Day	66,000	71,700	965	930

Table 36.5. Kraton-coated Balloons (1400 gm - All Day)

BURSTING ALTITUDE (feet)			RATE OF RISE (to common alt)	
Kraton	Control	Free Lift (gm)	Kraton	Control
99,800 *	-	4,000	1,414	-
108,520 *	110,932	2,850	1,398	1,173
94,485 *	103,800	2,700	1,199	1,096
100,000 *	-	2,700	1,347	-
76,800 **	115,633	1,600	1,146	921
96,800 **	-	2,700	1,358	-
45,650 **	100,148	2,700	1,237	928
102,953 **	80,400	3,800	1,388	1,020
102,000 **	105,200	2,900	1,287	1,217

* Coated inside
** Coated outside

ML-537 type, the standard 110,000 foot balloon. Flight tests were conducted on 10 samples using ML-537 as controls on some of the flights. Free lifts varied from 1600 to 4000 gms. At the higher free lifts, inflation of ML-537 was difficult since the balloon is made of a low modulus film and stretched so as to become very elongated. Launching was also difficult in all but the lightest breeze. However, no problem was encountered in inflating and launching the Kraton balloons.

Overall, the Kraton-coated balloons rose faster than the control balloons by speeds from 70 to 350 ft/min. (Comparisons were available for 6 of the 10 balloons). Most of the flights were about 200 ft/min faster. Half of the Kraton balloons were Kraton-coated on the inside, half on the outside.

While no attempt was made to fly these Kraton-coated balloons in pairs, the balloons coated on the inside appear to do better on both altitude and ascent rate than those coated on the outside. As indicated above, Kraton is attacked by ozone. Perhaps this has some effect in producing the difference in altitude and ascent rate, although more data would be required to evaluate this factor. Also, an analysis is required of the altitude regions of flight where the Kraton coating tends to improve the ascent rate.

36.2.5 Surfactant Materials

As a result of studying recent literature (Davies and Rideal, 1963; and Interfacial Circulation..., 1966) on the effects of some surfactant materials on reducing evaporation from bodies of water and other surface phenomena, it was decided to investigate the effects of certain coatings on balloons. The evaporation theory (Davies and Rideal, 1963; and Interfacial Circulation..., 1966) was that turbulent diffusion was responsible for the loss of water and that the use of a surfactant reduced this effect. Flow patterns in the vicinity of the air-water interface were affected by a layer of cetyl alcohol (hexadecanol) on the water. By analogy, it was thought that air flow at the air-balloon interface might be changed similarly.

A series of experiments were conducted indoors using 30-gram pilot balloons with weights in their necks, and allowing them to oscillate from the ceiling like a pendulum. Time and distance of travel were noted for 1-1/2 swings for untreated balloons and controls, followed by tests on the same balloons treated with various materials; that is, hexadecanol, corn starch, graphite (all applied both wet and dry), Tide (wet), floor wax, glycerine and ethylene glycol. The only two materials showing significant differences were wet corn starch and wet graphite. Balloons treated with these materials moved consistently through a longer path than control balloons in the same time interval.

Seven pairs of flights were made to evaluate effects on a group of 150-gram balloons carrying radiosondes aloft. Of these, four pairs were tested to determine effects of corn starch, the other three to determine effects of graphite. The balloons were treated generally by immersing them in a solution or mixture of corn starch and water, or graphite and water. After inflation and just prior to launch, the balloons were again sprayed, or the solution applied by using cheesecloth soaked in that solution. Results are shown in Table 36. 6. All three graphite-coated balloons performed better than their controls. However, in the case of the corn-starch-treated balloons, it was a tie; two were better and two worse than their controls.

Table 36. 6. Surfactant-coated Balloons

DATE ALL DAY	FLIGHT NO.	BURSTING ALTITUDE (feet)	R/R*	R/R TO COMMON ALT.	TOTAL LIFT (gm)	COATING	REMARKS
24 July 69	367	19,400	1175	1175	2700	control	
24 July 69	366	33,000	1141	1045	2700	corn starch	Immersed in solution first, then inflated and sprayed.
25 July 69	368	54,500	839	839	2700	control	
25 July 69	369	59,400	932	925	2700	graphite	Immersed in solution first, then inflated and sprayed.
28 July 69	370	40,000	983	1017	2700	control	Launch reel used.
28 July 69	371	30,000	1083	1083	2700	graphite	Turned inside-out, and solution poured in. Sprayed after inflation. Launch reel used.
30 July 69	372	41,800	873	862	2700	control	
30 July 69	373	36,000	992	992	2700	corn starch	Turned inside-out and solution poured in. Sprayed after inflation.

* Rate of Rise

Table 36.6. Surfactant-coated Balloons (Cont.)

DATE ALL DAY	FLIGHT NO.	BURSTING ALTITUDE (feet)	R/R*	R/R TO COMMON ALT.	TOTAL LIFT (gm)	COATING	REMARKS
6 Aug 69	392	56,900	858	847	2700	control	
6 Aug 69	393	48,180	906	906	2700	corn starch	Immersed in solution, then inflated and sprayed and wiped with cheese-cloth.
6 Aug 69	394	52,360	968	968	2700	control	
6 Aug 69	395	60,100	930	929	2700	corn starch	Sprayed with solution after inflation.
8 Aug 69	401	53,600	935	935	2700	control	---
8 Aug 69	402	57,500	988	989	2700	graphite	Washed twice in cold water. Immersed in solv. before inflation. Solution applied with cheesecloth.

*Rate of Rise

Keeping the balloons moist during at least a part of the flight may be a problem. The corn-starch-coated balloons appear to dry more rapidly than the graphite-coated ones. Also, the flights were made in the summer. A problem might arise when the surface temperatures are below freezing. More data are needed to evaluate the materials more reliably, and larger size balloons or larger inflations are required to cover a wider range of Reynolds numbers. Also, other materials which do not freeze or evaporate so rapidly might be investigated.

36.2.6 Modification of Streamline Neoprene Balloons

Attaching a semi-conical neoprene tail to a spherical neoprene balloon increases its ascent rate from approximately 1000 to 1700 feet per minute. This type of balloon, in standard use by the Army for flights to 75,000 feet in the daytime, is known as Balloon ML-541. As the balloon rises and inflates, the tail is drawn up until at about 50,000 feet it becomes essentially a spherical balloon at double its initial diameter.

During an inflation test with air, at a balloon plant, it was noted that the lower 2 feet of the tail would not inflate and be drawn up on the spherical balloon. (The neck of the tail balloon is tied off since previous tests with the neck open did not provide any improvement in ascent rate over a balloon with a tied tail neck.) When two 1 inch vertical slits were cut in the tail right above its neck, the entire tail would be drawn up onto the spherical balloon as it inflated, thus allowing for complete use of the streamlining effect. Another benefit was visualized as a result of the slitting. It was felt that as the balloon approached 50,000 feet, the stresses on the tail would force it to split where the slits were placed. Once a neoprene balloon tail starts to tear, it generally tears rapidly, large sections of it ripping off. This would increase the free lift of the balloon above 50,000 feet, where the tail is no longer of any benefit.

As a result, a series of flights were made starting out at the free lift normally employed with this balloon - 2500 gms. Later this was varied to include other free lifts. At the 2500-gm free lift, significant increases in ascent rate were noted above that of control balloons having no slits. (Table 36.7). Even though in numerous instances the neck ripped off the tail at launch (the train line goes through the tail neck to an inner neck on the spherical balloon), performance was still better than that of the control balloon in each of the nine pairs of flights. In one case, the slit-tail balloons rose by more than 300 feet per minute faster than the control balloons.

Another series of flights was made at 3,500 gm free lift, but the results showed no improvement. This is possibly due to the fact that the greater the inflation, the lower in altitude the slit will rip. It is believed that the slitting

Table 36.7. Streamlined Balloons,
(Two slits near tail neck) 2500 gm Free Lift

BURSTING ALTITUDE (feet)		RATE OF RISE (ft/min)	
Slit Tail	Control	Slit Tail	Control
79,700	83,350	1,775	1,740
77,400	76,550	1,887	1,686
83,800	84,400	1,976	1,620
82,500	78,300	1,950	1,813
74,400	75,800	1,797	1,747
76,800	80,300	1,864	1,712
81,250	82,300	1,751	1,718
SLITS AT MIDTAIL			
79,100	83,800	1,766	1,693
83,700	54,875	1,820	1,764

Table 36.8. Streamlined Balloons
(with two slits in tail) 3500 gm Free Lift

BURSTING ALTITUDE (feet)		RATE OF RISE (ft/min)	
Slit Tail	Control	Slit Tail	Control
71,000	81,000	2,052	1,858
68,450	78,700	1,860	1,892
50,890*, **	72,000	1,621	1,853
72,500*	76,550	1,898	1,963
71,000*	72,000	1,802	1,837
81,600*	78,500	1,858	1,813
76,000	73,000	1,818	1,751
74,100	57,000	1,760	1,932
77,500	82,200	2,013	1,724

* Slits midway up tail

** Hole tied off

technique will have applicability to the development of higher-altitude, fast-rise balloons currently being initiated.

36.2.7 New Fabrication Technique

Streamline neoprene balloons, type ML-541, are more cumbersome and time-consuming to manufacture than spherical balloons. Generally, the streamline balloon involves the manufacture of two spherical balloons and cementing or gel-adhering of one balloon to a semi-conical section of the other. Considerable space and rigging are required for these processes.

A new technique has been conceived and is being tried on an experimental basis. It consists of dipping the form into a coagulant and then into a tank of latex to form the spherical or top balloon. The form and gel are then dipped into a second coagulant to exactly two-thirds of the fluted section of the form. It is then withdrawn and dipped into a tank of latex to a depth of two inches above the depth of the second coagulant. The tip of the neck of the second gel is snipped, then each gel is separately inflated as indicated in Figure 36.1, "Procedure for Making Integral Tail Streamlined Balloon." After drying, the top balloon is pulled through the neck of the tail balloon to provide a longer tail. A number of details on the processing are omitted for brevity.

A limited number of balloons were fabricated using this process - mostly small ones weighing approximately 250 grams. Some were flight-tested and showed promise. Effort is continuing to produce the full-scale balloons of the ML-541 size.

36.2.8 Fast-rise Balloons for Artillery Applications

Radiosonde soundings in Southeast Asia for artillery purposes are seldom required to exceed 35,000 feet. Use of the larger, more expensive balloons such as the ML-537 and ML-541 is not economical. It was proposed that a low-cost, small-volume, low-altitude, fast-rise balloon be developed for such applications. Initially, requirements were drafted for a balloon to achieve an altitude of 11 kilometers (36,000 feet) at a minimum ascent rate of 475 meters per minute (1,560 feet per minute) with an ultimate goal of 550 meters per minute. A small, streamlined, neoprene balloon was visualized weighing perhaps 300 gms, which would provide the necessary performance. While awaiting receipt of a formal directive, an effort was made to determine the size and shape of the top spherical part of such a balloon. Data were obtained on a balloon 40-inches long weighing 150 gms. This balloon provided a minimum ascent rate of 400 meters per minute (1300 feet per minute) when inflated with 75-80 cubic feet of hydrogen. In response to informal inquiries from artillery users as to the availability of such a balloon,

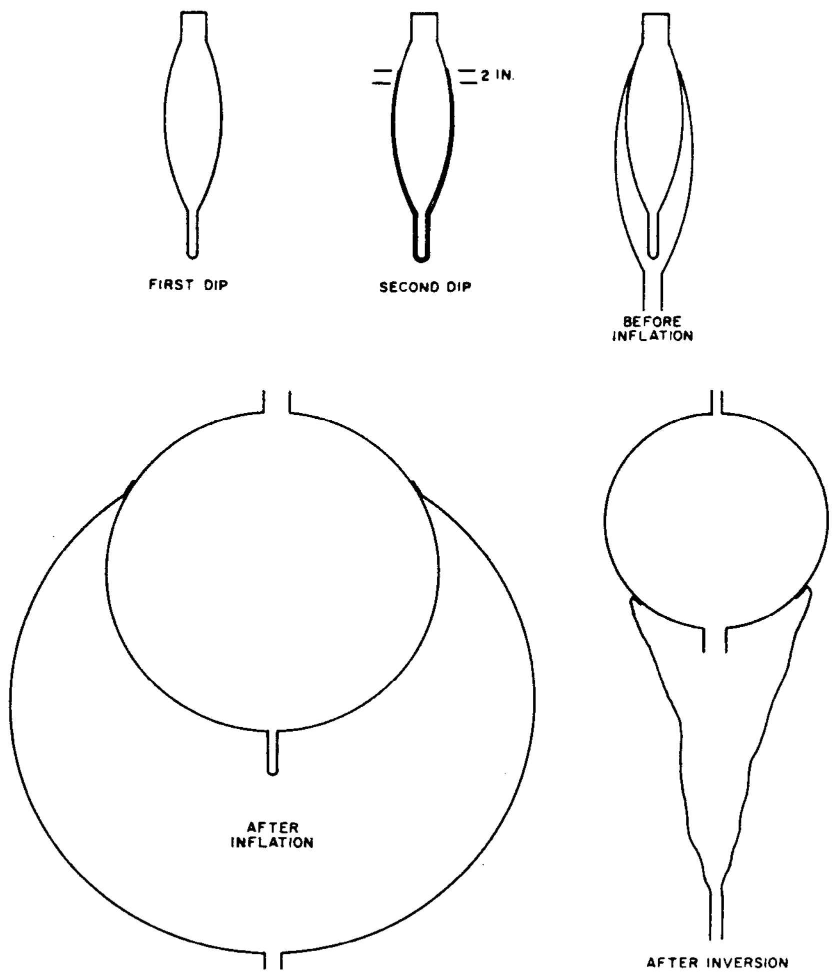

Figure 36. 1. Procedure for Making Integral Tail Streamlined Balloon

200 models were tested further. It was found that better than 85 percent met the minimum ascent rate and altitude, with many exceeding 1400 and 1500 feet per minute. A directive has been issued to buy a large quantity of these balloons for use in Southeast Asia.

Acknowledgments

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